An Introduction to Forecasting Weather

BY

P. RAYMOND ZEALLEY
(F.R Met.Soc.)

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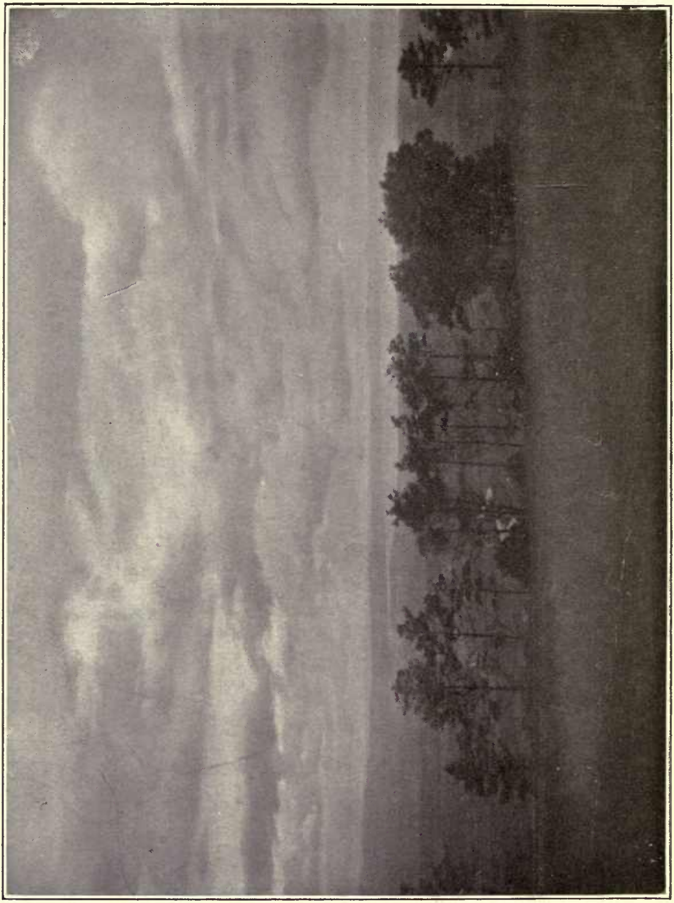

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Preface

THE object of this treatise is to elucidate in a clear and simple way the principles of "Forecasting Weather."

For more extensive information on this subject the book *Forecasting Weather*, by Sir Napier Shaw, F.R.S., should be consulted. I am indebted to the Meteorological Office for the use of descriptions of "Isobars" from the *Meteorological Glossary*, and to Messrs. Percival Marshall & Co. for references from *Meteorological Instruments*. Also to the Council of the Royal Meteorological Society for references which appear in the notes at finish. I should like to thank N. K. Johnson, B.Sc., for courteously reading through the original MS.

The frontispiece, a reproduced photo of "Strato-Cumulus," is from the collection of my late brother, A. E. V. Zealley, A.R.C.S., to whom I am also indebted.

P. RAYMOND ZEALLEY.

SHOEBURYNESS,
May, 1922

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An Introduction to Forecasting Weather

GENERALLY speaking, the elements move about in systems. Thus, with a knowledge of the movements of these systems, it is possible to forecast the weather.

The "Weather Map," or "Synoptic Chart," as it is technically termed, is compiled by the insertion of observations which are received from various meteorological stations and observatories.

I propose, first of all, to explain how a synoptic chart is made; and, secondly, to illustrate how it is possible to forecast weather from it.

Upon a blank-outlined map of a region are inserted at the positions of recording stations various meteorological readings. It is important to note that these readings are recorded at the various stations at precisely the same time and date.

Since the heights above sea-level of recording stations vary to a great extent, the observed heights of the barometer should be reduced to sea-level, and thus made uniform.

For purposes of convenience it is useful to know that the "bar" is equal to 100 "centibars," which equals 1000 "millibars," shown as "mb." This equals 29·53 inches, which equals 750·1 millimetres (mm.).

Next, lines are drawn through and connecting all stations reporting the same degree of any set of like observations.

Usually, on a synoptic chart, the only lines that are drawn are through places of equal pressure; these lines are termed "isobars." They may be very irregular in shape, but there is a distinct tendency for them to run more or less parallel to each other.

On the synoptic charts issued by the Meteorological Office isobars are drawn denoting every two millibars difference in pressure, e.g. 1016 mb., 1018 mb., those of high pressure being marked with a thick line, and those of low pressure with a thin line.

The isobars 1014 mb. and upwards are drawn thick, representing high pressure, and isobars 1012 mb. and downwards are drawn with a thin line, representing low pressure.

Other synoptic charts can be made, however, where isobars are drawn for a larger difference of pressure, say, every five millibars, and the lines can be drawn all of the same thickness; but the former method is a great aid when only a cursory glance is taken at the chart.

It follows that the closer the isobars are together the greater is the rise or fall of the barometer per unit distance. This is termed "barometric gradient."

Wind blows from a region of high pressure to a region of low pressure, and its velocity will be increased if the difference in pressure is great, i.e. if the isobars are close to each other. Hence the strength of the wind depends on the steepness of the "barometric gradient."

If the isobars are very close together, consequently the "barometric gradient" is steep (the height of the barometer varying very much between one place and another); this would indicate very strong winds. Conversely, when the isobars are at a considerable distance

apart, in other words the pressure varying little, much lighter winds can be safely predicted.

Areas of high pressure are technically called "anti-cyclones," and areas of low pressure "cyclones."

Sometimes high pressure areas are called "highs," and low pressure areas are called "lows," or "depressions."

The direction of the wind does not travel directly from a region of high pressure to a region of low pressure (i.e. cutting the isobars at right angles, as it were), but it follows approximately the course of the isobars with a slight inward tendency towards the region of low pressure. The angle which the wind makes with the isobar is usually about 35 degrees.

The direction and strength of the wind are shown on the chart by the insertion of small arrows.

A most simple method of determining a region of low pressure is by "Buys Ballots' Law," which states: If in the northern hemisphere one stands with one's back to the wind, the lowest pressure will always be on the left hand, whereas in the southern hemisphere the lowest pressure will be on the right hand. Hence, when in England, if one stands with one's back towards the wind, the barometric gradient slopes down towards the left, steeply if the wind is strong, and less steeply if the wind is light. Conversely, knowing of the existence of a region of low pressure, the approximate direction of the wind can be determined.

An example of a simple synoptic chart is illustrated in Fig. 1.

A complete synoptic chart has much other information shown. Lines connecting places of the same temperature

recorded at the same time, called "isotherms," are placed on the map. If isotherms are not actually drawn

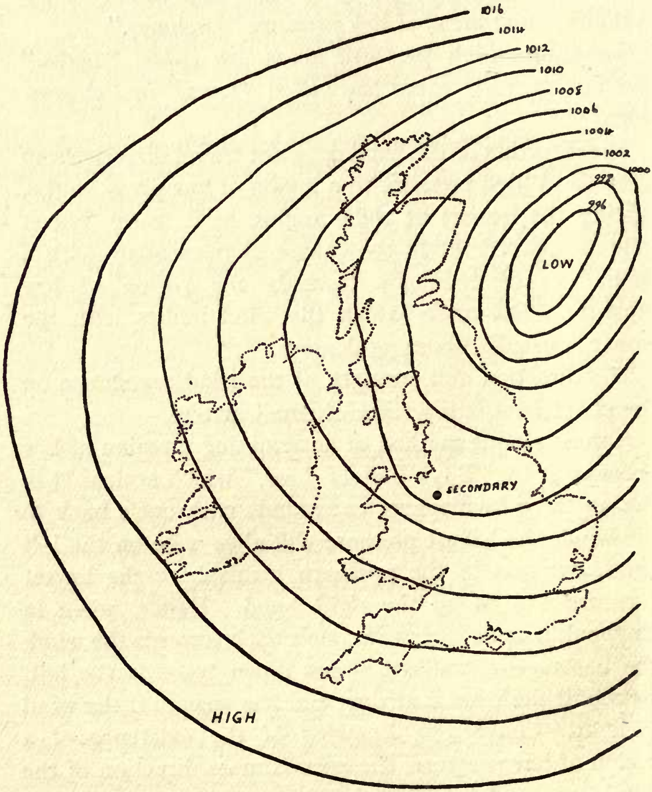


Fig. 1. "Simple Synoptic Chart."

the temperature is invariably inserted by figures at the position in question. The temperature is usually

recorded in degrees Fahrenheit, the scale used, however, will be stated on the chart.

The types and amount of high and low cloud, and visibility, may also be inserted.

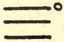
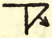
On the synoptic charts issued by the Meteorological Office, the following notation is used. On other synoptic charts, however, different codes may be in vogue.

As previously stated, the wind near the ground surface is shown by small arrows. Figures enclosed within the small circle give the velocity of the wind in m.p.h. A blank circle (with no figures enclosed) indicates a calm.

By the numbers of feathers on the wind direction arrows is defined the "wind force," according to the "Beaufort notation," used only for surface observations, viz.:

0	represents	wind less than 1 m.p.h.
1	,,	a light air of 1 to 8 m.p.h.
2	,,	a slight breeze of 4 to 7 m.p.h.
3	,,	a gentle breeze of 8 to 12 m.p.h.
4	,,	a moderate breeze of 13 to 18 m.p.h.
5	,,	a fresh breeze of 19 to 24 m.p.h.
6	,,	a strong breeze of 25 to 31 m.p.h.
7	,,	a high wind of 32 to 38 m.p.h.
8	,,	a gale of 39 to 46 m.p.h.
9	,,	a strong gale of 47 to 54 m.p.h.
10	,,	a whole gale of 55 to 63 m.p.h.
11	,,	a storm of 64 to 75 m.p.h.
12	,,	a hurricane of above 75 m.p.h.

The state of the weather is inserted, the following symbols being used to represent conditions indicated:—

	Sign		Sign
Aurora		Gale	
Glazed frost		Glazed roads	
Solar halo		Lunar halo	
Solar corona		Lunar corona	
Fog		Mist	
Thunder		Thunder storm	
Snow		Hail	
Rain falling		Overcast	
Sky $\frac{3}{4}$ clouded		Sky $\frac{1}{2}$ clouded	
Sky $\frac{1}{4}$ clouded		Sky clear	

SEA DISTURBANCES.

Rough		High	

p indicates passing showers
d ,, drizzle.
r ,, rain.
s ,, snow.
rs ,, sleet.
h ,, hail.
q ,, squally.
t ,, thunder.
l ,, lightning.
v ,, visibility.
e ,, wet air (without rain falling).
m ,, mist.
f ,, fog.

b indicates blue sky.
bc ,, partly clouded sky.
c ,, cloudy sky.
o ,, overcast sky.
g ,, gloom.
u ,, ugly appearance.
w ,, dew.
x ,, hoar frost
y ,, dry air (humidity less than 60%)
z ,, dust haze (the turbid atmosphere of dry weather).

Having these data all inserted, the synoptic chart is made, and it is possible to forecast the weather with a series of such charts, bearing in mind the following statements, which enable us to determine the direction and the velocity of the wind, and deduce the type of weather to be expected.

(*a*) The shape of the isobars usually assumes one of the typical forms, seven in number, which I will describe later.

(*b*) These curves or isobars are always in movement, and by experience from the types of isobars this movement can usually be forecasted, thus enabling us to *predict the weather.*

(*c*) *The direction of the wind* can be forecasted in accordance with Buys Ballots' Law, which has been previously explained.

(*d*) *The velocity of the wind* depends on the distance apart of the isobars, also previously stated.

(*e*) *The type of weather* is related to the shape of the isobars, and not directly to their closeness together.

Summarised, the seven types of isobars referred to are:—

1. Cyclone. / Depression. / Low.
2. Anti-cyclone. / High.
3. Secondary depression. / Secondary.
4. "V" depression.
5. Wedge of high pressure.
6. Col.
7. Straight isobar.

Since so much depends on these forms, I will deal with them in detail.

1. **"The Cyclone"** is a movement of the atmosphere in a spiral direction round an area of low pressure.

The isobars are always closed, generally into the shape of a circle or oval. Corresponding to a basin, the pressure is less towards the centre.

The size of the cyclone may vary to a great extent, some cover only a small space, say, a part of an English

county, whereas others may cover a large space, say, a whole continent.

Again, they may vary in the sense that some are deeper than others, "a deep depression" being one where the pressure is very low near the centre, whereas a "shallow depression" can be described as having a low pressure near the centre, although not varying much in its surrounding districts.

In the northern hemisphere wind blows round a depression in an anti-clockwise direction, whereas in the southern hemisphere it blows in a clockwise direction (Fig. 2).

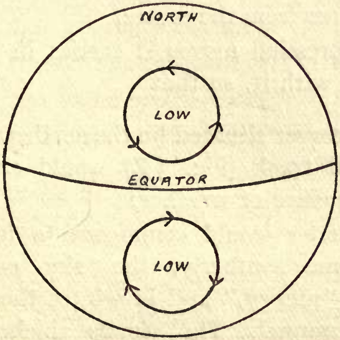


Fig. 2. To illustrate direction of wind for a "cyclone" in the Northern and Southern Hemispheres respectively.

An inference may be drawn from this, inasmuch that in the northern hemisphere, since the air in front of a cyclone is coming from the south, it will be warmer than the air which flows from the north in the rear of a depression. This is very noticeable in the winter.

In most cases it can be safely stated that on the east side of a depression it is raining or overcast, while on the

west side it is finer. On the north-east side heavy rain may be expected, and near the centre, too, we may expect rain.

It is interesting to note the phenomena near the centre of a region (not necessarily the centre of the cyclone) where there is a complete change of wind direction from south, on the east side, to north, on the west side of the depression. Here we may expect heavy rain, and frequently "squalls."

On the west side, the region of northerly or north-westerly winds, the rain cloud is broken up into detached clouds, which become more separated and less rainy the further one goes from the centre.

As the depression moves it carries its weather and wind system with it, so that

(I.) An observer situated (in the northern hemisphere) in its central track (Fig. 3 Z) would experience the following sequence of weather:

The barometer would commence to fall, the wind would become southerly, the sky overcast, and the weather "muggy," and in winter the temperature well above normal. The clouds thicken, the wind becomes stronger, and rain commences to fall. As the centre approaches the barometer falls lower, the wind and rain become heavier, and as the centre passes right over there are often gusts of wind or "squalls," with heavy rain "clearing showers." The barometer ceases to fall, then commences to rise, the clouds show signs of breaking, and the wind changes round, blowing from a northerly point, and is often stronger than it was before the centre passed.

As the centre of a cyclone moves away the wind and rain gradually cease; finally there are occasional showers, and then the sky clears.

The rate at which these changes take place depends on the size of the depression, and its rate of travel. Twenty-four hours is an average time for these changes to be gone through; however, it may be longer or it may be shorter. This is a typical sequence of weather, but there are many differences in individual depressions, some being rainy without much wind and vice versa.

(2.) If the depression passes to the north of the observer (Fig. 3 B) south-westerly winds will be noticed at first, with dull weather, becoming rainy. The wind will gradually "veer" to the west, when the centre is passing north, the barometer will begin to rise, and the wind will veer further to the north-west as the centre passes away. If the observer is a long way from the centre of the track he will perhaps experience only a slight fall of the barometer and cloudy weather.

(3.) If the depression passes to the south of the observer (Fig. 3 A) south-easterly or easterly winds will first be noticed, with much rain, the wind will "back" to the north-east or to the north, as the centre passes to the south.

The winds on the north side of a depression are usually less strong than those on the south side, the isobars on the polar side being less crowded together than those on the equatorial side. Thus a depression passing on the south gives less wind, but probably more persistent rain than one passing on the north.

The gloomy days with an east or north-easterly wind and rain all day are usually due to depressions passing to the south of the observer.

The easterly current on the north side of a depression frequently brings snow in the winter.

If high clouds are visible they will often be seen to be moving away from the centre of low pressure. Thus a south wind on the surface with high clouds moving from

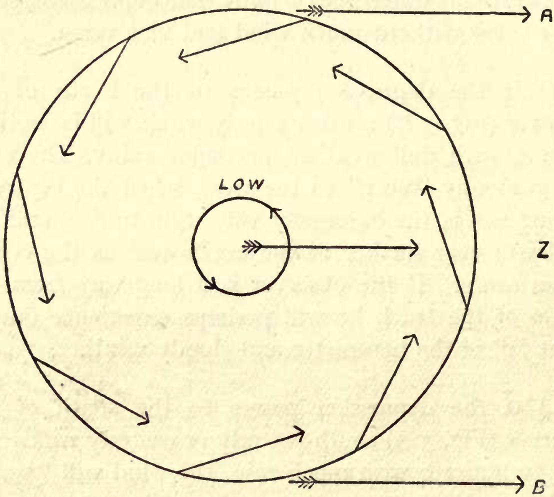


Fig. 3. "Cyclone" in Northern Hemisphere, to illustrate direction of wind, and conditions to observes in positions A, Z and B.

Note.—Large-feathered arrows indicate movement of cyclone. Small arrows indicate wind direction.

the west is a sure sign of the existence of a depression to the west.

At times, especially in summer, very small depressions are apt to form; several of these are sometimes seen on

the synoptic chart for the same day. Being shallow, they do not bring much wind, but heavy rain and thunderstorms in the summer.*

The phenomena in the southern hemisphere would be different on account of the winds blowing in a clockwise direction. The reader can, however, substitute the necessary changes.

It is here necessary to explain what is meant by the statement "wind backing or veering."

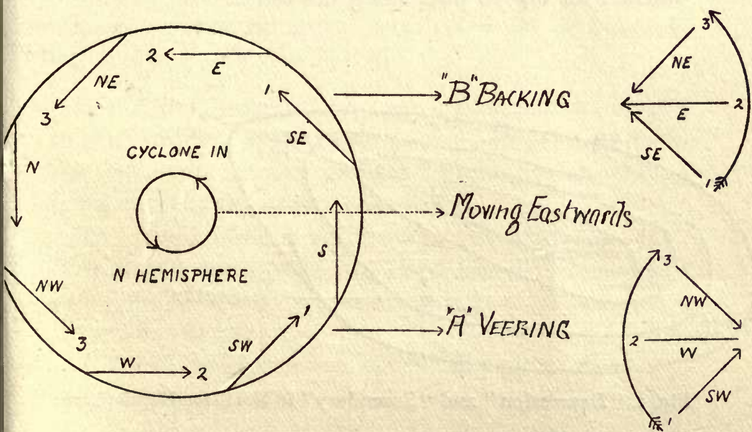


Fig. 4. To illustrate "veering" and "backing."

Note.—The winds are experienced in the sequence 1, 2, 3 to observers at "A" and "B" respectively.

It will be noticed that the direction of the wind in the usual cyclone moving towards the east, and in the northern hemisphere (when the depression is north of the observer) is one that follows the sun, going round from

* Meteorological Glossary.

S.W., W. and N.W. A wind which changes in this way, in the same way as the sun, is said to "veer" (Fig. 4 A).

When the wind changes the other way, as in the cyclone to the south of observer, in the northern hemisphere, the cyclone also moving east, the wind is then said to "back," "backing" meaning that the wind changes direction S.E., E. and N.E., against the apparent motion of the sun (Fig. 4 B).

In England a cyclone usually passes to the north; it is unusual for one to pass along the south.

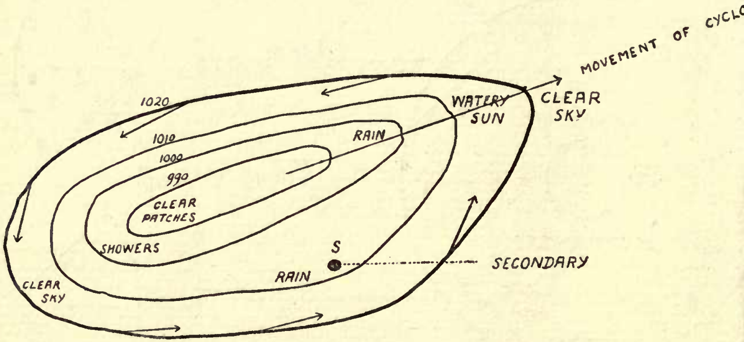


Fig. 5. "Depression" and "Secondary" in Northern Hemisphere.

If a depression is noted on the synoptic chart any particular day, and then noted on the chart of the following day, it will generally be noticed that it has moved in an easterly direction (to the right). Very rarely does a depression remain long in the one place, its drift usually being towards some point between N.E. and S.E. There are, however, exceptions.

Again, a cyclonic disturbance does not persist indefinitely, hence difficulty is often found in forecasting.

It is only occasionally during the year that a cyclone is so persistent, e.g. to cross the Atlantic from the U.S.A. to the United Kingdom.

The majority of cyclones that reach this country are born out on the Atlantic, their presence first being noticed by a fall in the barometer on the west coast of Ireland.*

In the typical depression there is a patch of clear sky over the centre, and a ring of cloud and rain all round this, but drawn out rather more to the front than the back, and again round this clear sky again. With this humidity comes the optical clearness, which we associate with coming rain (see Fig. 5).

2. **" Anti-Cyclone."** An anti-cyclone is the converse to the cyclone. The highest pressure isobars will be in the centre, the pressure gradually decreasing the farther one gets from the centre (Fig. 6).

The winds blow spirally outwards, and since anti-cyclones are often very large, and usually the distance apart of the isobars is greater than in a cyclone, hence the winds are lighter.

The anti-cyclone moves slowly, and often remains in the one locality for a considerable time. This brings fine weather, which persists. In the winter, however, frosts and fogs may be expected in the towns, but it can be assured persistent rain never falls. This dull weather is termed "anti-cyclonic gloom."

3. **" Secondary Depression."** A secondary depression often accompanies a cyclone. When this is so it will frequently be found to be on the southern side of the depression. The isobars of the depression make a bend

* Meteorological Glossary.

outwards, causing a small area of low pressure as in "S" (see Fig. 5).

The direction of the secondary runs more or less parallel with the depression, and it may even travel faster. It brings heavy rain, and gusty winds. In the summer thunderstorms are common, especially if the secondaries are shallow.

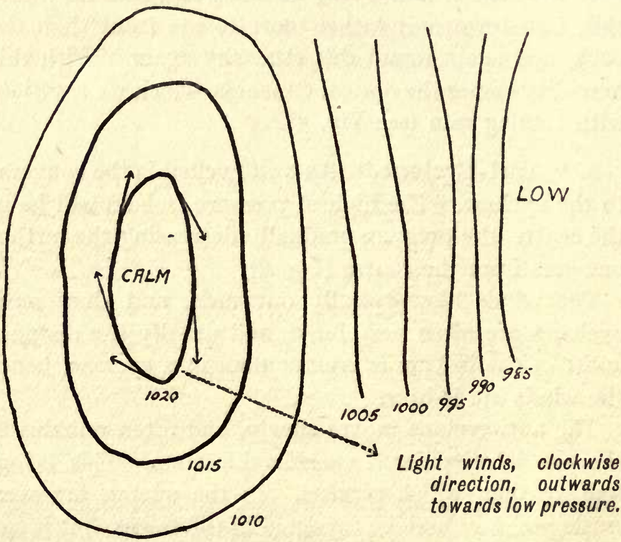


Fig. 6. "Anti-Cyclone" in Northern Hemisphere.

4. **"The 'V'-shaped Depression"** is, as its name implies, a portion of the isobars of a depression extended into the shape of a "v," with low pressure in its centre. It is like a continuation of the isobars moving outwards in a secondary (Fig. 7 "V").

If Buys Ballots' Law is applied the wind on the east side of the "V" depression is in a southerly direction, whereas on the west side it is in a northerly direction.

The sequence of phenomena that an observer would encounter if standing in front of the approach of a "V" depression would be first, southerly winds then driving

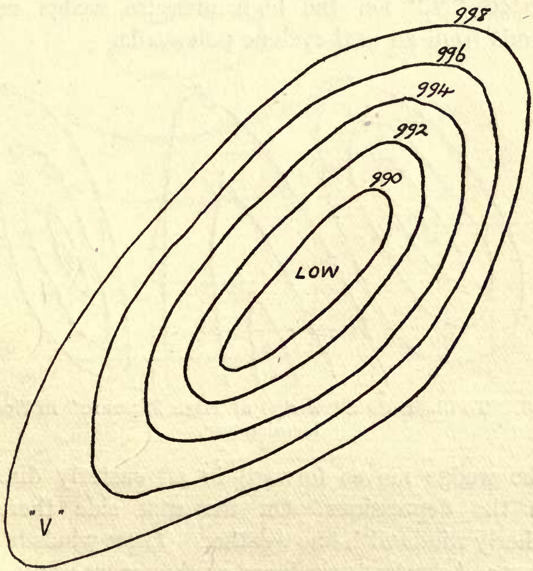


Fig. 7. "V"-shaped Depression.

rain, which together with the wind increases as the centre approaches. The barometer continues to fall. As the centre is overhead, violent squalls may be experienced. Now the wind is reversed, blowing from a northerly point, and the temperature in accordance falls

as the centre passes along to the right. The barometer rises, the sky clears, and the rain ceases.

5. **"Wedge of High Pressure."** Between two depressions there may be a wedge of high pressure (Fig. 8).

The shapes of the isobars usually are similar to an inverted "V," i.e. the high pressure wedge usually extends from an anti-cyclone polewards.

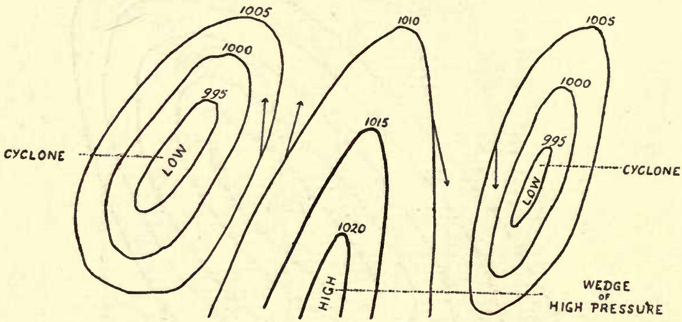


Fig. 8. To illustrate a "wedge of High Pressure" in Northern Hemisphere.

The wedge moves forward in an easterly direction with the depressions. On the east side there are northerly winds with fine weather. These winds become lighter and a calm is produced as the centre approaches. After the centre passes the wind "backs" to the S.W., clouds form and rain falls rapidly as the new depression approaches.

It is interesting and useful to note that should the weather clear up and the winds cease quickly after a depression has passed "a wedge" is no doubt approaching. In this case fine weather may be forecasted for a

few hours only, then bad weather from the second depression which follows may be predicted.

6. **The "Col"** is the name applied to the region of lower pressure which exists between two anti-cyclones (Fig. 9). Since the wind of an anti-cyclone in the

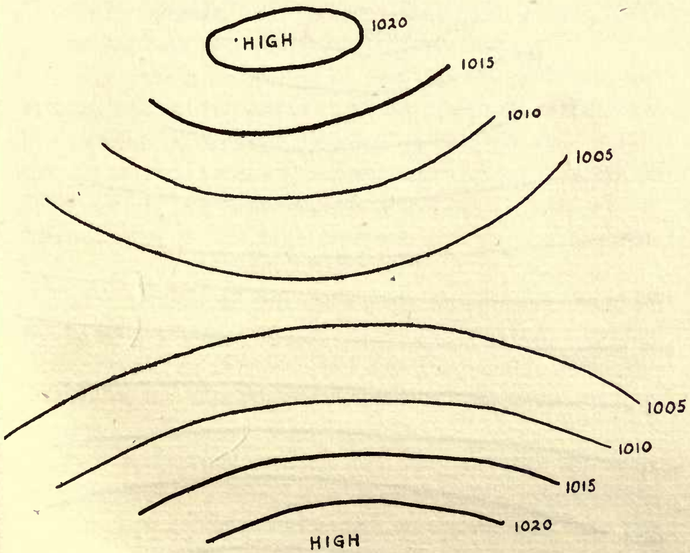


Fig. 9. To illustrate a "Col" in Northern Hemisphere.

northern hemisphere is in a clockwise direction, we have light winds from almost opposite directions very close to each other.

This will cause thunderstorms in the hot weather and fog in the cold weather.

7. **The "Straight Isobar"** as its name implies, may be considered as an isobar belonging to a system so large that the curvature of the lines is not appreciable (Fig. 10).

Usually in these latitudes the low pressure is to the north of straight isobars. Thus, in accordance with Buys Ballots' Law, the wind will be westerly.

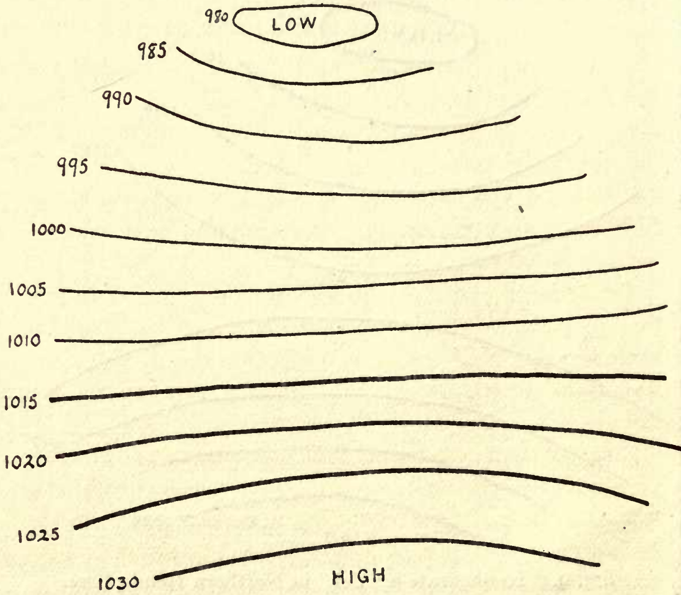


Fig. 10. To illustrate "Straight Isobars."

There may be a great range of weather in a region of straight isobars, for the northern side extends to a low pressure area, giving rain, and the southern side extends to an anti-cyclone, with fine weather.

Having thus described these seven types of isobars, their direction, and the speed of their movement may again be summarised, for in this climate the "cyclones," "secondaries," "V" depressions, and "wedges" usually move eastwards towards some point between N.E. and S.E. at a definite rate somewhere about 20 miles per hour.

The "anti-cyclones," their separating "cols" and "straight isobars" are often almost stationary, thus producing long periods of fine dry weather.

In conclusion, to be able to forecast with precision, the arrangement of the isobars and the positions of high and low pressure areas must be noted on the synoptic chart; the particular form of isobar must be considered to determine if the depression is a cyclone, secondary, or "V" shaped, or the high pressure area an anti-cyclone, wedge, col, or straight isobar.

The direction of the movement should be observed (and here experience is most necessary), and this, together with the aid of the previous synoptic chart, helps the forecaster to determine succeeding positions of the isobars.

Since a depression does not pass through an anti-cyclone it follows that if an anti-cyclone is on the western side of these islands, and a cyclone approaches from the Atlantic, there is a tendency for the depression to pass to north or south.

Temperatures must also be forecasted, i.e. on the north side of the depression in the northern hemisphere cold easterly winds with snow are probable in winter. Thus endless varieties of weather can be forecasted, provided that these conditions are observed.

Notes

The following notes on (1) moisture, (2) clouds, (3) rain, (4) snow, (5) hail, (6) wind, may be of use to the reader:

(1) MOISTURE. The amount of water vapour which the air can contain is dependent on the temperature. The lower the temperature of the air, the less is its capacity for moisture. The air is said to be "saturated" when its full capacity for vapour has been reached.

(2) CLOUDS. When the air is cooled below the "dew point" (the point of saturation of the air described above) moisture becomes visible in the form of cloud or fog. Thus we have the composition of all cloud forms, with the one exception of "cirrus" clouds (of the upper layer), which are composed of ice crystals. These last clouds have a pure white appearance.

(3) RAIN is produced by the cooling of the air, and the consequent condensation of the water vapour it contains, and in most cases this cooling is produced by the expansion of the air, in ascending from lower to higher levels in the atmosphere, clouds usually being a stage in rain formation.

By the "amount" of rain is meant the height to which the rain would stand if it did not evaporate, run off, or soak into the ground. Thus one inch (1 in.) of rain would indicate a height of one inch of rain on the surface, provided the above conditions were observed.

The prevailing south-west wind of the British Isles comes from the Atlantic, charged with moisture. In the western districts of these Isles it has to rise until it reaches the highest summits. In doing so it becomes cooled, and thus its capacity for moisture is reduced, consequently it parts with some of its moisture in the form of rain.

Hence in the western districts the rainfall is decidedly greater than it is in the eastern districts, as can be judged by a glance at any rainfall map of these Isles.

(4) SNOW. A snowflake can be described as a collection of small ice crystals, which are formed by the condensation of water vapour below the freezing point.

A small mass is at first formed; this gradually collects more moisture on its surface, which also freezes, so the flake is formed.

There is a great variety of patterns of these ice crystals. Since the flake is very loose in construction, having air spaces between the crystals, it follows that snow is much lighter than its equal volume of water. Usually it takes about one foot of snow to produce one inch of water.

Snow is unknown in the tropics at sea-level, but can be produced anywhere, provided the altitude is sufficiently high.

Sleet is a mixture of rain and snow.

(5) HAIL is formed when warm and moist air rapidly rises to a height, expanding, and then becoming cooled, or when met by a very cold layer of air, which causes the moist air to condense and eventually freeze. These drops fall owing to gravity, and in falling gather fresh ice on the surface, and the size may become considerable.

Usually they are small in size, but cases have been reported in which the size of some have been equal to the size of an orange.

Small and soft hail usually falls in this country.

Hail often occurs with thunderstorms.

(6) WIND is produced by the flowing of convection currents.

The prevailing wind of the British Isles is the south-westerly wind. This, together with the effect of the gulf stream drift, has a pleasing effect upon the climate of the British Isles, which can be described as very changeable, especially as regards temperature.

The velocity of the wind, speaking generally, has a diurnal variation, the greatest being about mid-day, and the least at night.

On mountains the reverse is the case, the greatest wind being during the night, and the least during the day.

In gales the wind attains a high velocity of, say, 70 to 80 miles per hour (m.p.h.).

In gusts the wind may momentarily attain a velocity of say 100 m.p.h.

It is useful to note, for purposes of conversion, that miles per hour (m.p.h.) may be converted approximately into feet per second (f/s) by multiplying by 3/2.

The effect of "land" and "sea" breezes is worthy of note on the area around the coast.

"Sea" breezes being formed during the day, and "land" breezes being formed during the night.

Sea breezes are due to the land heating during the day quicker than the sea is heated.

The air above the land expands, rises, and the pressure is lowered. Hence the air above the sea flows towards the land, i.e. from an area of higher to lower pressure.

"Land" breezes are formed owing to the sea (which has been heated during the day) retaining its heat longer than the land, which cools quickly at night. The air above the sea rises, the pressure is lowered, and a "land" breeze flows towards the area of low pressure.

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